IS 7356-2 (2003): Installation, Observation and Maintenance of Instruments for Pore Pressure Measurements in Earth and Rockfill Dams - Code of Practice, Part 2: Twin Tube Hydraulic Piezometers [WRD 16: Hydraulic Structures Instrumentation]

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भारतीय मानक

मिट्टी और राकफिल बाँधों में दाब मापों के लिए संस्थापन, प्रेक्षण तथा रख-रखाव की रीति संहिता

भाग 2 दोहरी टयूब वाले द्रवचालित

(दूसरा पुनरीक्षण)

Indian Standard

INSTALLATION, OBSERVATION AND MAINTENANCE OF INSTRUMENTS FOR PORE PRESSURE MEASUREMENTS IN EARTH AND ROCKFILL DAMS — CODE OF PRACTICE

PART 2 TWIN TUBE HYDRAULIC PIEZOMETERS

(Second Revision)

ICS 93.16

BUREAU OF INDIAN STANDARDS
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NEW DELHI 110002

April 2003

Price Group 8

Hydraulic Structures Instrumentation Sectional Committee, WRD 16

FOREWORD

This Indian Standard (Part 2) (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Hydraulic Structures Instrumentation Sectional Committee had been approved by the Water Resources Division Council.

Pore space in soils generally contains both air and water. Pressures may be developed in the pore space due to the loading of the soil mass or due to other factors, such as, seepage and capillary action. The seepage pressure and pore water pressure in saturated soils and the resultant of the pore air pressure and capillary pressure in partially saturated soils provide information for the proper understanding of the behaviour of the soil mass.

Installations of piezometers in earth fills and their foundations provide significant quantitative data indicating the magnitude and distribution of pore pressures and their variations with time and other patterns of seepage, zones of potential piping and proper functioning of the filter media and effectiveness of under seepage control measures. Piezometers properly installed in earth dams will:

a) indicate potentially dangerous conditions that may adversely affect the stability of a dam and its appurtenant structures.
b) provide guidance for regulating the rate of fill placement and/or controlling moisture conditions in the fill during construction.
c) help monitor, during and after construction, the behaviour of dams and the foundations and appurtenant structures.
d) provide basic data for improvement of design practices and criteria that will promote safer and more economical design and construction of earth and rockfill dams and appurtenant structures.
e) enables evaluation of the effectiveness of the grout curtain.

One instrument commonly used for this purpose, namely, the twin tube hydraulic piezometer, is covered in this standard.

This standard was first published in 1976. The first revision of the standard was taken up in 1993 to incorporate certain changes found necessary in the standard in the light of comments received from the users. The major changes in the first revision were inclusion of information on electrical transducers and readout equipment and readings with electrical transducers.

This second revision is also being taken up in the light of comments received from the users. In first revision the applicability of twin tube hydraulic piezometers (*see* **7.1.3**) was made limited for elevation of difference of less than 9 m between the lowermost tip and gauge. In this revision this aspect has been more elaborately explained and '9 m' has been replaced by '5 m'.

The composition of the Committee responsible for the formulation of this standard is given at Annex C.

Indian Standard

INSTALLATION, OBSERVATION AND MAINTENANCE OF INSTRUMENTS FOR PORE PRESSURE MEASUREMENTS IN EARTH AND ROCKFILL DAMS — CODE OF PRACTICE

PART 2 TWIN TUBE HYDRAULIC PIEZOMETERS

(Second Revision)

1 SCOPE

This standard (Part 2) covers the details of procedures for installation, maintenance and observation of twin-tube hydraulic piezometers installed in earth and rockfill dams for measuring pore pressures. Both foundation and embankment piezometer tips are covered.

2 REFERENCE

The following standard contains provisions which through reference in this text, constitutes provision of this standard. At the time of publication the edition indicated was valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent edition of the standard indicated below:

IS No.	*Title*
3624 : 1987	Specification for pressure and vacuum gauges (*first revision*)

3 TERMINOLOGY

3.0 For the purpose of this standard, the following definitions shall apply.

3.1 Air Entry Value — It is the pressure required to force air through a saturated ceramic porous disc; also known as bubling pressure.

3.2 Pore Pressure — It is the fluid pressure developed in the water and air present in the pores of a soil mass.

3.3 Pore-Air Pressure — It is the pressure developed by the air, present in the pores of a soil mass.

3.4 Pore Water Pressure — It is the pressure developed by the water present in the pores of a soil mass.

3.5 Total Stress — It is the sum of intergranular stress, pore water pressure and pore air pressure.

3.6 Neutral Stress — It is the total pressure exerted by water and air present in the soil mass.

3.7 Response Time of a Piezometer Tip — It is a period required for equalization of the pore water pressure in the vicinity of that piezometer tip.

4 PIEZOMETER TIPS

4.1 A piezometer tip consists of a hollow cylindrical device which is machined or moulded from a plastic (nylon or polypropylene) or any non-corrodible material. The 8 mm OD piezometer tubing is connected directly to the piezometer tips by 3 mm pipe through 8 mm tube compression connectors. To prevent earth material and air from entering the piezometer circuits, ceramic filter discs are installed in the open ends of the piezometer tips by 'O' rings and stainless steel end plates. The two types of tips are (a) foundation type, and (b) embankment type. Details of the foundation and embankment tips are shown in Fig. 1, 2 and 3.

4.1.1 *Foundation Type Piezometer Tips*

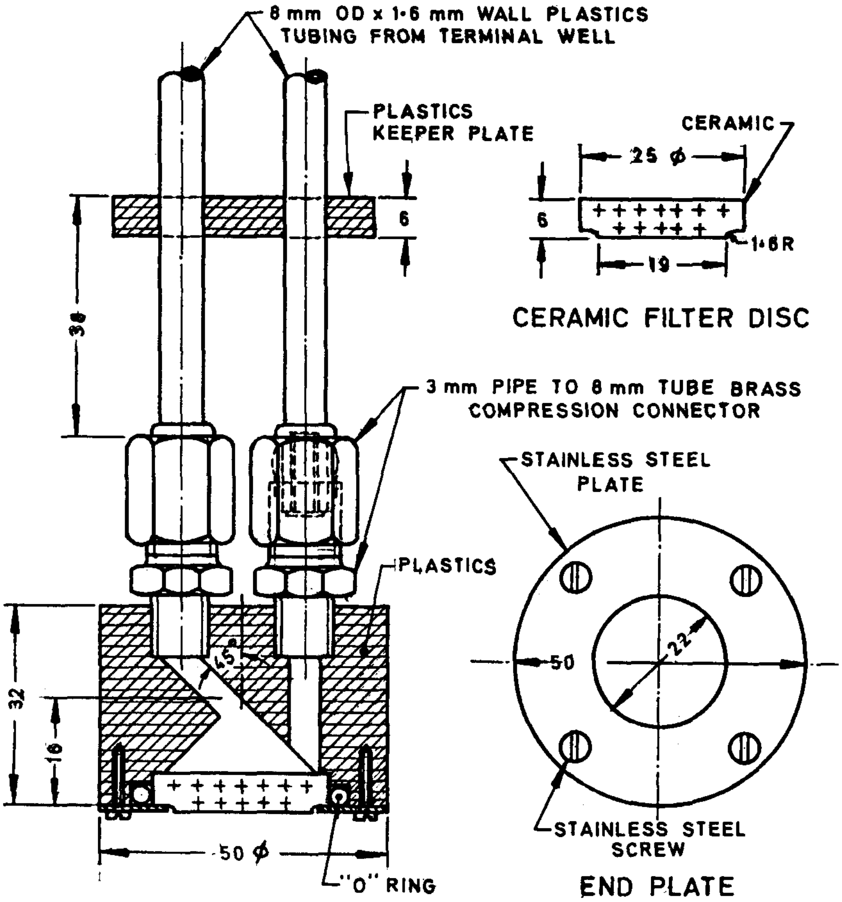
This tip contains a single ceramic filter disc, 25 mm in diameter and 6 mm thick, and utilizes plastic tubing of 8 mm OD and 1.6 mm wall thickness to extend the piezometer lines to a desired-elevation in the dam foundation. The air entry value of the disc should not be less than 147 kN/m^2 (1.5 kgf/cm^2) and it should have a permeability not less than 2×10^{-7} cm/s.

4.1.2 *Embankment Type Piezometer Tips*

This tip has two 25 mm diameter and 6 mm thick ceramic filter discs fastened to the tip as shown in Fig. 3. When these tips are installed in the dam embankment, the flat sides of the discs should be placed horizontally. The air entry value of the disc should not be less than 147 kN/m^2 (1.5 kgf/cm^2) and it should have a permeability not less than 2×10^{-7} cm/s.

4.2 Protection and Testing of Piezometer

Care should be taken during the storage of the peizometer tips as well as all materials for the instrument installation to avoid plugging the tips with dirt and debris and contaminating the filter discs with



All dimensions in millimetres.

FIG. 1 FOUNDATION TYPE PIEZOMETER TIP (WITH CERAMIC DISC)

oils. The connection between the piezometer tips and the 8 mm OD tubing can be broken by rough handling and the porous discs embedded in the tips can be cracked.

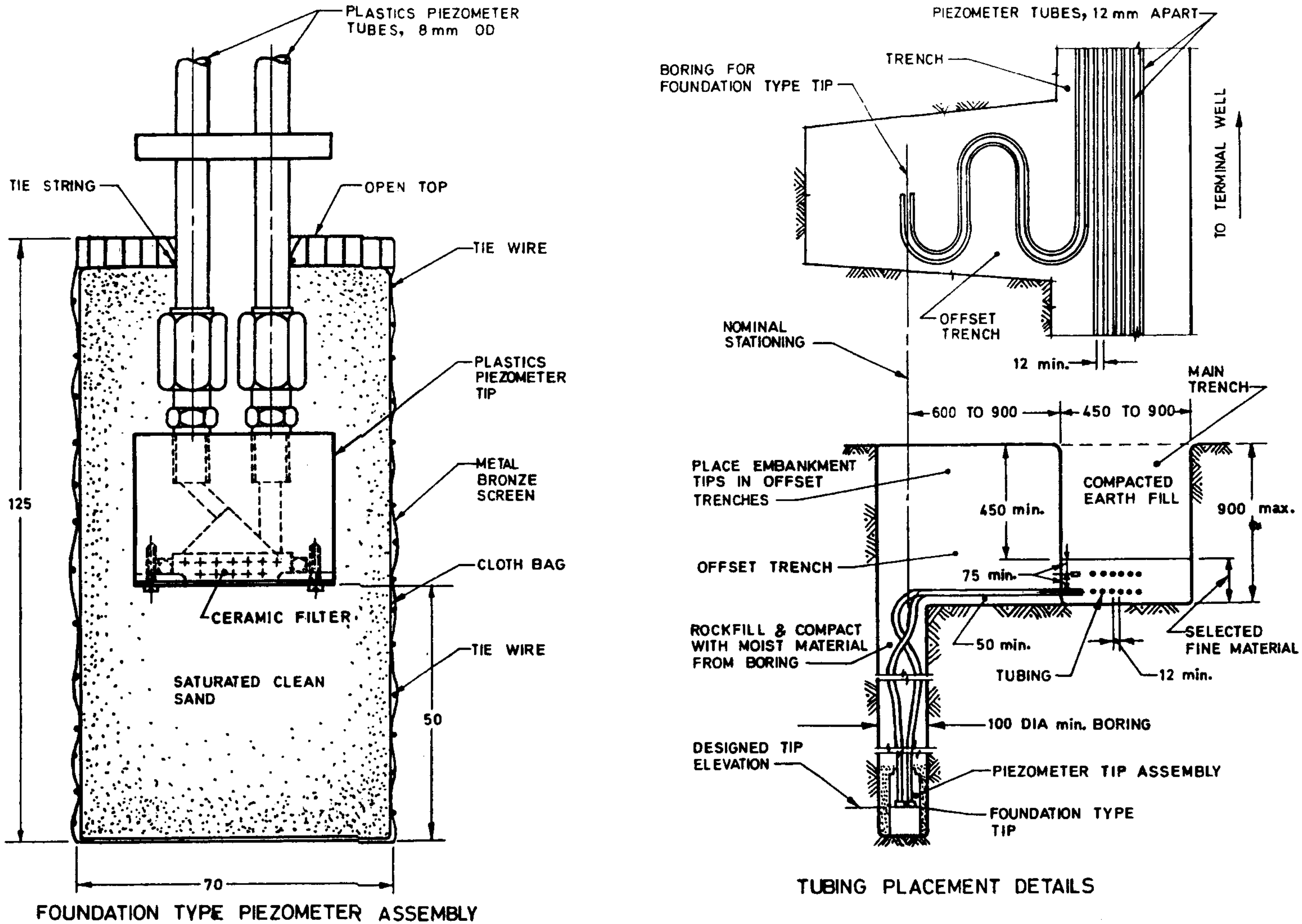
Each piezometer tips should be tested after being received at the project by placing a sheet of rubber over each porous disc and holding it in place with a block of wood and a 'C' clamp. Water should then be forced through the tubes to ensure an open passage through the tip, and finally each tip should be tested under a pressure of 350 kN/m^2 to check for leaks at the compression connections between the tip and the tubings, one tube from each tip should be temporarily plugged during the pressure testing. Prior to installation of all piezometer tips they should be boiled in water for approximately 15 min to saturate the porous disc.

5 TUBING

5.1 Two 8 mm OD × 1.6 mm wall thickness plastics (polypropylene) tubes connect each piezometer tip with the recording gauges in the terminal well. Each coil of tubing is normally 300 m long but since the piezometer tips may require more than 300 m of tubing to connect them with gauges in the terminal well, the lengths of the tubing needed for each tip should be estimated from the installation drawing, after allowing for slack (1 to 1.5 m per 100 m length of tubing), approximately 5 m for extensions in the terminal well and contingencies. All tubes should be marked, coupled and recoiled prior to installation in the embankment.

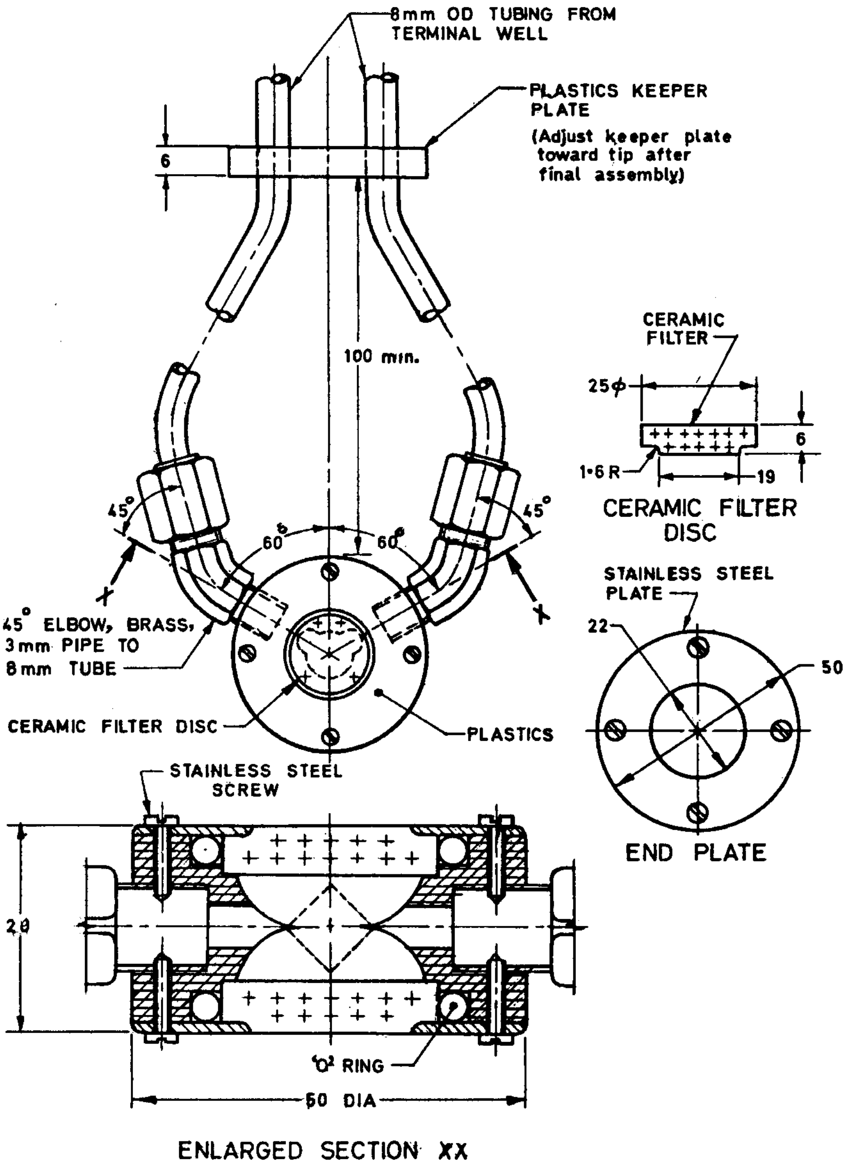
5.1.1 *Protection and Care of Tubing*

Each coil of tubing is crimped or sealed by the extruder prior to shipment. These seals should not be removed until required. Before connecting lengths of tubing, a few centimetres should be removed from the sealed ends and discarded. To protect against dirt entering the tubing during placement, all exposed ends of tubing should be crimped and taped until finally installed. Plastic tubing is extruded from a relatively soft material and can be cut by angular rock fragments



All dimensions in millimetres.

FIG. 2 FOUNDATION TYPE PIEZOMETER TIP AND INSTALLATION DETAILS



All dimensions in millimetres.

FIG. 3 EMBANKMENT TYPE PIEZOMETER TIP (WITH CERAMIC DISC)

or other sharp objects. Hence, coils of tubing should be stored away from the embankment placing operations. In addition, coils of tubing that are being used for installation of the apparatus on the embankment should be stored in timber boxes or within sections of steel barrels. Exposure to air will not impair the physical or chemical properties of the tubing. However, the tubing should be protected and covered, as far as practicable, from prolonged exposure to direct sunlight. If the tubing is collected on a rack on the downstream edge of the embankment during construction of the dam, the rack should be covered with tarpaulin. Plastic tubing should be protected from fire. Care should be exercised to protect the plastic tubing against rodents when the tubing is stored in warehouses.

5.1.2 *Testing of Tubing*

A running inspection should be made of each coil of plastic tubing to check for surface irregularities prior to installation. To ensure that each tip is open, water should be pumped through each tube. Likewise, to ensure that each length of tubing will withstand pressure, the tubing should be tested under air or gas pressure 10 percent in excess of maximum anticipated operative pressure, before being placed in operation.

During this pressure check one end of a length of tubing should be plugged by a compression type coupling on which a pipe cap is installed, and the other end adapted and connected to a source of gas pressure.

5.1.3 *Identification of Tubing*

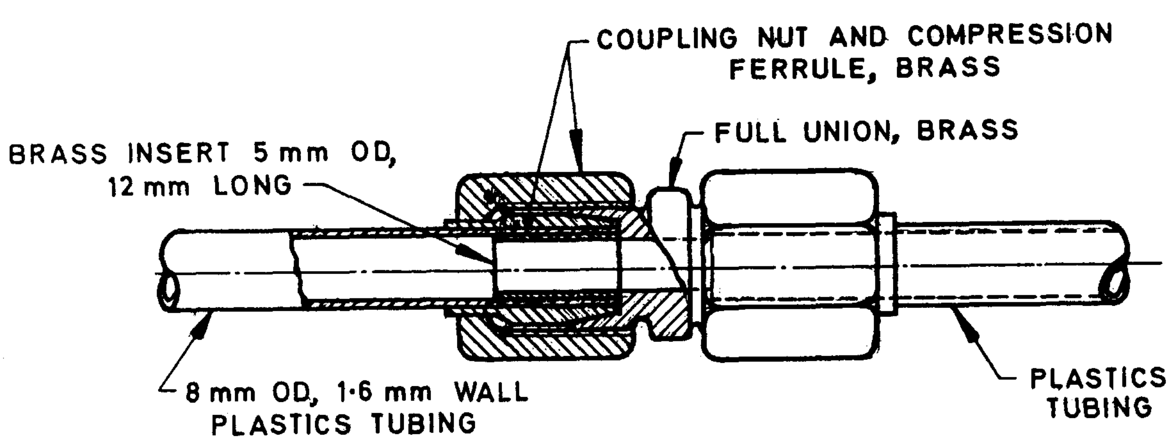
Tubing should be marked or identified with permanent markers every 15 m by the use of plastics or metal bands stamped with appropriate piezometer numbers. Suitable identifications should include the piezometer number and an 'I' or 'O' to indicate inlet or outlet tubes. The use of adhesive tapes to hold the identification is not recommended because moisture can loosen the adhesive. Temporary identification may be obtained by writing the number of tip and identification on a strip of paper and covering with transparent plastic tape. Permanent identification is necessary to prevent errors in making up to proper terminal well connections, and to ensure correct splicing if the tubing is accidentally cut or broken.

6 COMPRESSION TYPE COUPLING

Tubing extruded from plastic materials such as polyvinylidine chloride (PVNC) and from various thermoplastic has no field solvent and generally cannot be cemented. Lengths of tubing are, therefore, connected by compression type brass couplings. A special brass insert should be installed at the end of the plastic tubing to form a suitable connection. Figure 4 illustrates a typical assembly of a compression type connection between lengths of 8 mm OD tubing suitable alternative compression joints may be used to couple the tubing. Use of warm water is recommended to soften the plastic tubing before the brass insert is installed. In addition a fixed wheel special tube cutter is recommended for use on the plastic. Figure 5 shows the details and procedure to be followed in making up connections between the plastic tubing and the gauges and valves in the piezometer terminal well. A pair of 150 mm pliers, open end wrenches, or crescent wrenches should be used to tighten the compression couplings. It is recommended that a moderate amount of torque be applied when making these connections. Generally, the coupling nut should be screwed into the union until the threads on the coupling nut are nearly hidden. Trial connections between lengths of tubing and from the tubing to the valves and gauges should be made and pressure tested before actual installation.

7 TERMINAL WELL

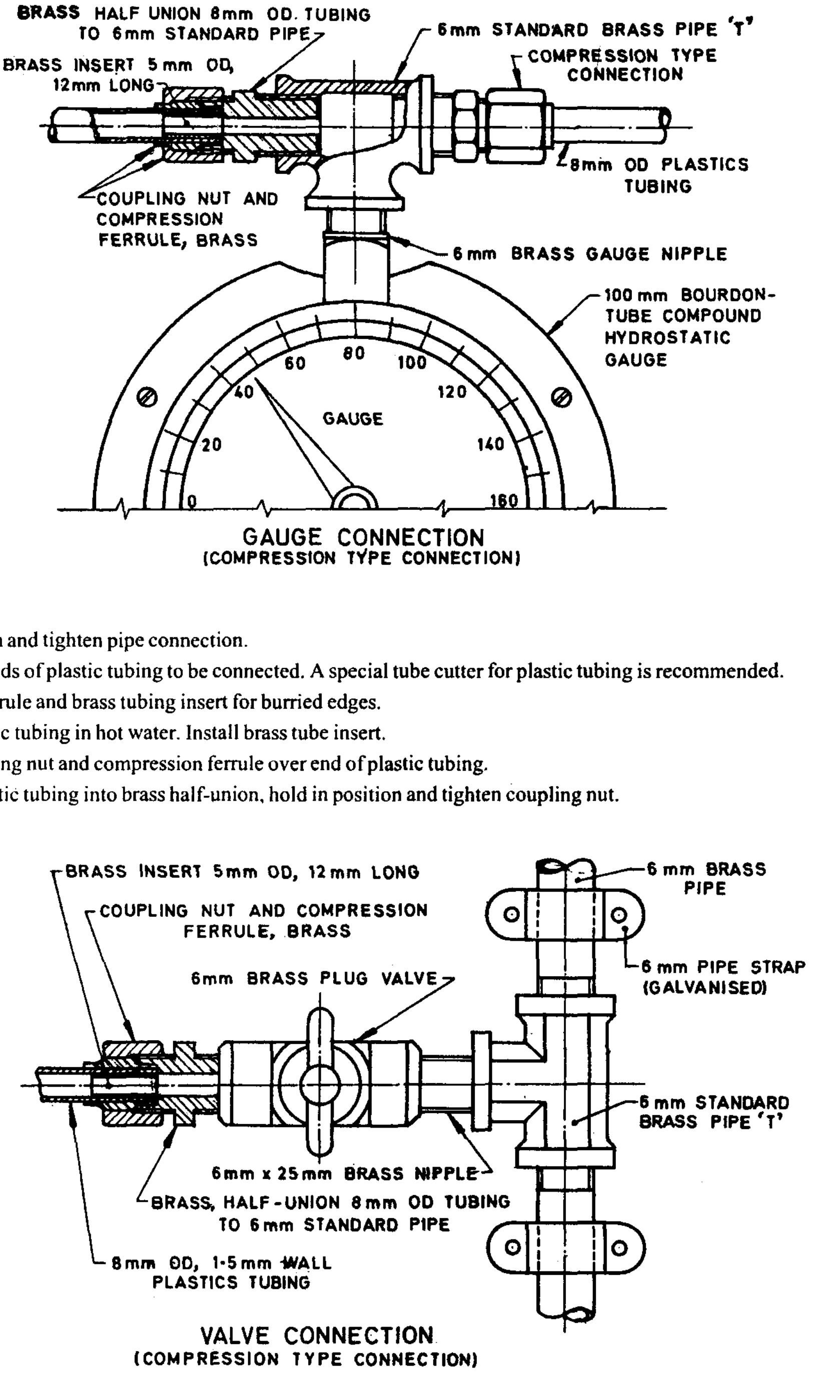
7.1 Pore pressure observations are taken in the terminal well which is constructed on the downstream toe. Equipment to be installed in the terminal well includes the manifold system, water pumps, air trap gauges, valves, water filter, auxiliary fittings and electrical equipment. All connections should be leak proof and should be tested, under a pressure 10 percent in excess



Procedure

1. Square end or ends of plastic tubing to be connected. A special tube cutter for plastics tubing is recommended.
2. Inspect brass ferrule and brass tubing insert for burred edges.
3. Dip end of plastics tubing in hot water, install brass tube insert.
4. Slip brass coupling nut and compression ferrule over end of plastics tubing.
5. Push end of plastics tubing into brass union, hold in position and tighten coupling nut.

FIG. 4 COMPRESSION TYPE COUPLING



Procedure

1. Install half union and tighten pipe connection.
2. Square end or ends of plastic tubing to be connected. A special tube cutter for plastic tubing is recommended.
3. Inspect brass ferrule and brass tubing insert for burried edges.
4. Dip end of plastic tubing in hot water. Install brass tube insert.
5. Slip brass coupling nut and compression ferrule over end of plastic tubing.
6. Push end of plastic tubing into brass half-union, hold in position and tighten coupling nut.

FIG. 5 GAUGE AND VALVE CONNECTIONS

of maximum anticipated operative pressure subject to a minimum of 350 kN/m^2 air pressure before being placed in operation. Typical terminal well layout is shown in Fig. 6. Some suitable means of carrying the tubing to the well may be adopted. The terminal well should be constructed and pressure apparatus installed as soon as the construction conditions permit. Till such time a permanent terminal house is not constructed, it is advisable to provide a temporary panel arrangement for measuring construction pore pressure which can produce most critical condition for stability.

7.1.1 *Location of the Well*

The floor of the terminal well is located at downstream toe of the dam at suitable elevation, preferably above tail water level and accessible at all the times. Suitable location with approach roads for inspecting the well and telephone facilities, if necessary, to communicate the

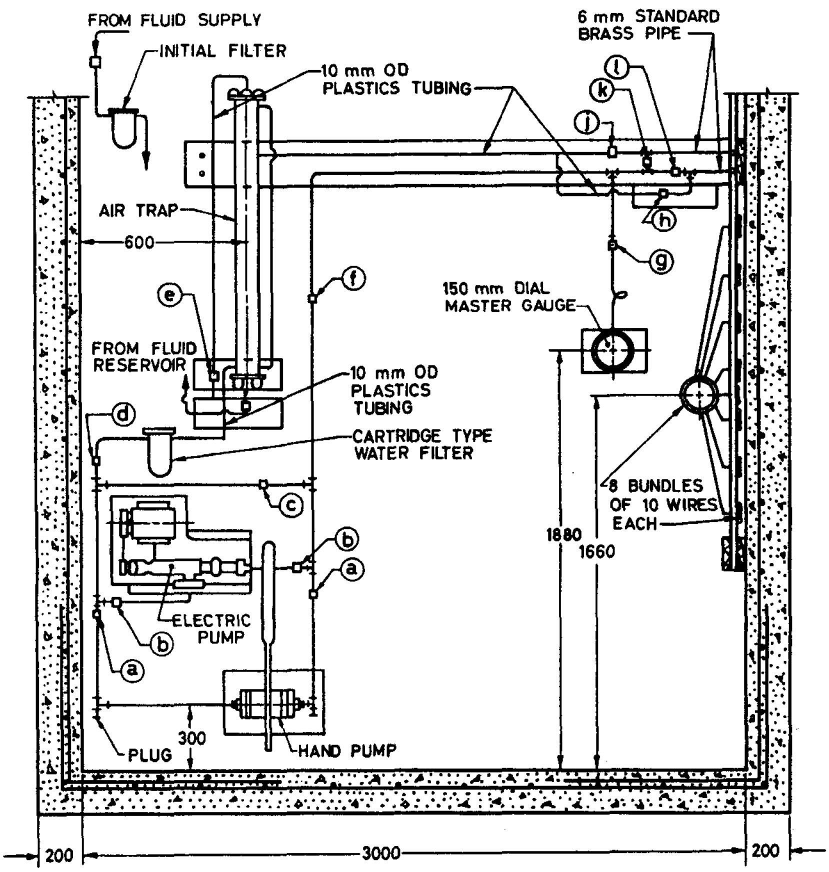
readings to the head office is essential. The base of the terminal well is located below the water table elevation, a suitable size of sump is required to facilitate removal of seepage water. If the terminal well is proposed in a relatively impervious embankment, suitable arrangement of drainage pipe (500 mm pipe) should be provided from the sump of the well to the downstream face of the dam or to the foundation drains (*see* Fig. 6).

7.1.1.1 In areas where the terminal well is subjected to serve freezing temperatures suitable precautions should be taken to protect the well by insulation. An airtight wooden frost floor and frame with suitable opening (500 mm × 600 mm) should be constructed at 3 000 mm from the base slab of the well. In order to have good insulation, at least 1 500 mm thickness of selected fine or impervious material on all the sides to the entire depth of the well should be provided.

7.1.2 *Waterproofing, Painting, Ventilation and Lighting of the Terminal Well*

The exterior well of the terminal well should be applied by a suitable waterproofing material to prevent the seepage of water into the well. Drainage arrangements with suitable size of sump or a standard pipe connection to the sump should be provided to the terminal well depending on its location, to facilitate removal of the seepage water (*see* **7.1.1**).

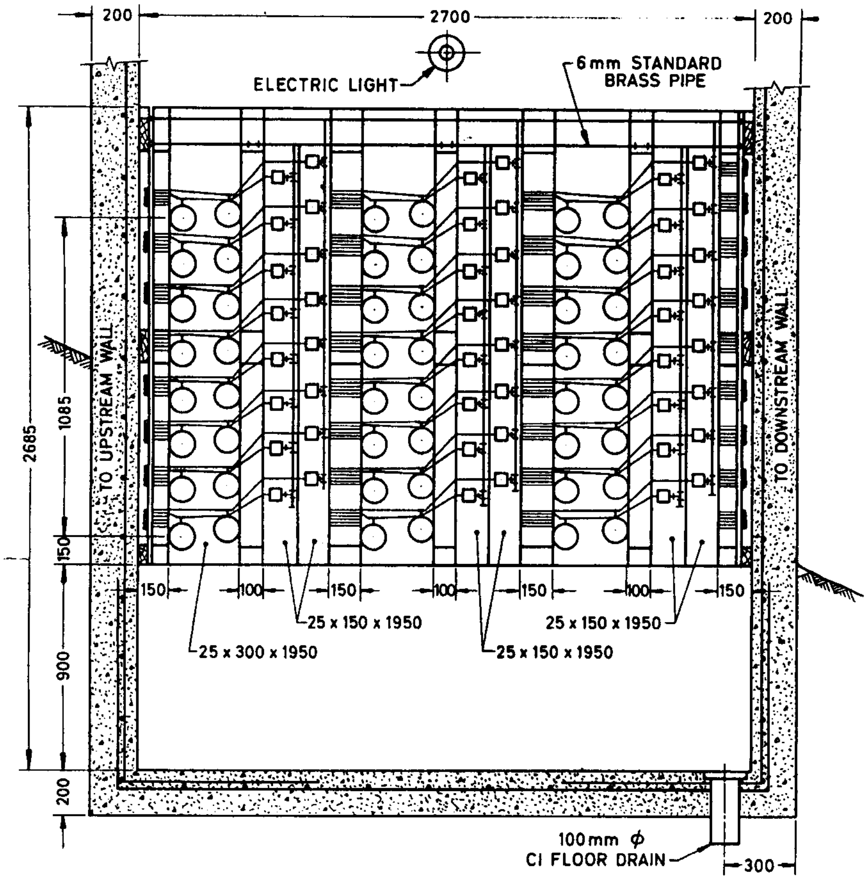
7.1.2.1 White paint should be applied to the interior walls of the well in order to have good visibility and appearance in the well.



(*a*) Hand pump shut off valve
(*b*) Electric pump shut off valve
(*c*) Bypass relief valve
(*d*) Pressure check valve
(*e*) Bleeder valve
(*f*) Manifold pressure valve (1)
(*g*) Safety valve on master gauge (7)
(*h*) Manifold inlet valve (6)
(*j*) Outlet flushing valve (4)
(*k*) Manifold outlet valve (5)
(*l*) Inlet flushing valve (2)

All dimensions in millimetres.

FIG. 6A SECTIONAL VIEW OF UPSTREAM WALL



All dimensions in millimetres.

FIG. 6B SECTIONAL VIEW OF LEFT WALL

7.1.2.2 Depending on local conditions, suitable ventilation and lightning system should be provided in the terminal well. The ventilation system may consist of an exhaust fan situated inside and near the top of the well.

7.1.3 At many location in the foundation of the dams, the lower most tip of a hydraulic piezometer is installed at considerable depth. These tips are likely to indicate high pore water pressure due to reservoir water loads. If the pressure indicated by the tip is positive than this may be taken as correct. In case a negative pore water pressure is anticipated then the elevation difference between this tip and the gauge should not exceed 5 m.

7.2 Equipment in the Terminal Well

7.2.1 *Pumps*

The pump may be either hand operated, electrically operated or a combination of both. The hand operated test pump may be assembled for vertical mounting. When electrical power is available, electrically operated pumps should be preferred.

7.2.2 *Air Trap*

Air trap assemblies made from steel pipe and from plastic are shown in Fig. 7 and 8 respectively. The plastic air trap is favoured for visibility. When water is circulated through the system, air bubbles can be observed as they pass through the sections of plastic tubings connected to the inlet and outlet or the air trap. Air from the trap can be released through the bleeder valve. Piezometer liquid should be supplied to the system from a 50-litre or 100-litre tank bracketed to the wall above the manifold system. A filter pipe or tube should be installed between the supply tank and the top of the terminal well. Very little fluid is needed after the tubes are once filled.

7.2.3 *Manifold System*

The manifold system comprising of brass or stainless pipe (6 mm nominal bore) is used to connect the 8 mm OD piezometer tubing, to the valves, pumps, gauges and air trap. The system is arranged so that the piezometer circuit is independent and the manifold is common to all units. All pipes and tubes should be

blocked away from the walls on wood framing which is rigidly fixed to concrete. All threaded connections should be made leakproof. The manifold is a double circulating system. By regulation of the proper sequence of valves, water can be pumped towards the tip through any desired piezometer tube. At certain locations in the manifold pipe system the 6 mm brass or stainless steel pipe is replaced by 10 mm OD plastic tubing for observing passage of air bubbles in the system.

7.2.4 *Master Gauge*

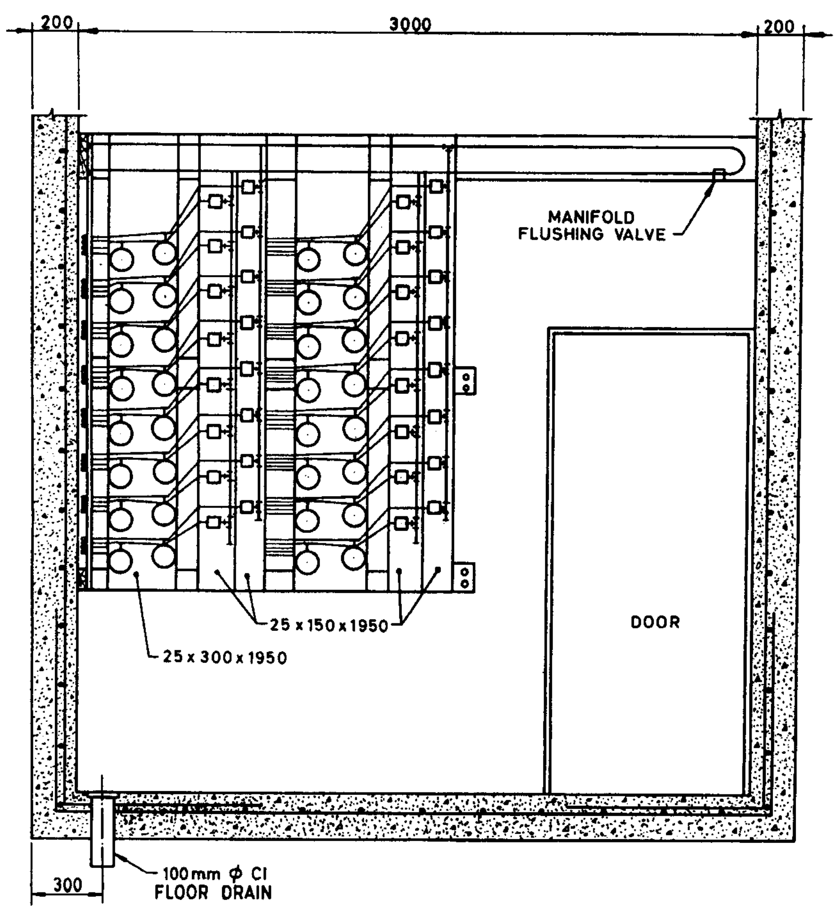
A bourdon-type compound hydrostatic gauge (*see* IS 3624) of diameter at least 150 mm and of required range commensurate with the height of dam, calibrated in centimetres of water and mounted for top connection, is used to measure both positive and negative piezometer pressure. In addition the master gauge is used to calibrate and furnish datum for the small separate gauges. To satisfy the minimum flow requirements of the installation any air in the bourdon-tube elements should be replaced with fluid. The inlet of all gauges, both the master gauge and the individual separate gauges are therefore placed at the top of the gauge case (top connection) where the fluid can continually replace the air. A mercury manometer, if provided in the terminal well in addition to the master gauge, may be useful for cross-checking.

7.2.5 *Separate Gauges*

Two bourdon-tube compound hydrostatic gauges of diameter at least 100 mm calibrated in centimetres of water and mounted for top connection are installed on each of the two incoming tubes from each piezometer tip. After stable conditions have been reached (that is an air free system obtained), pressure at each tip can be observed on its pair of gauges. This twin-gauge installation permits a cross-checking of pressure for each tip. After installing the gauges, suitable measures should be taken to prevent corrosion at the points where the nipple enters the gauge case.

7.2.6 *Fitting*

All connections between the plastics tubing and the gauges and valves within the terminal well are made with compression type brass fittings.



All dimensions in millimetres.

FIG. 6C SECTION OF DOWNSTREAM WALL

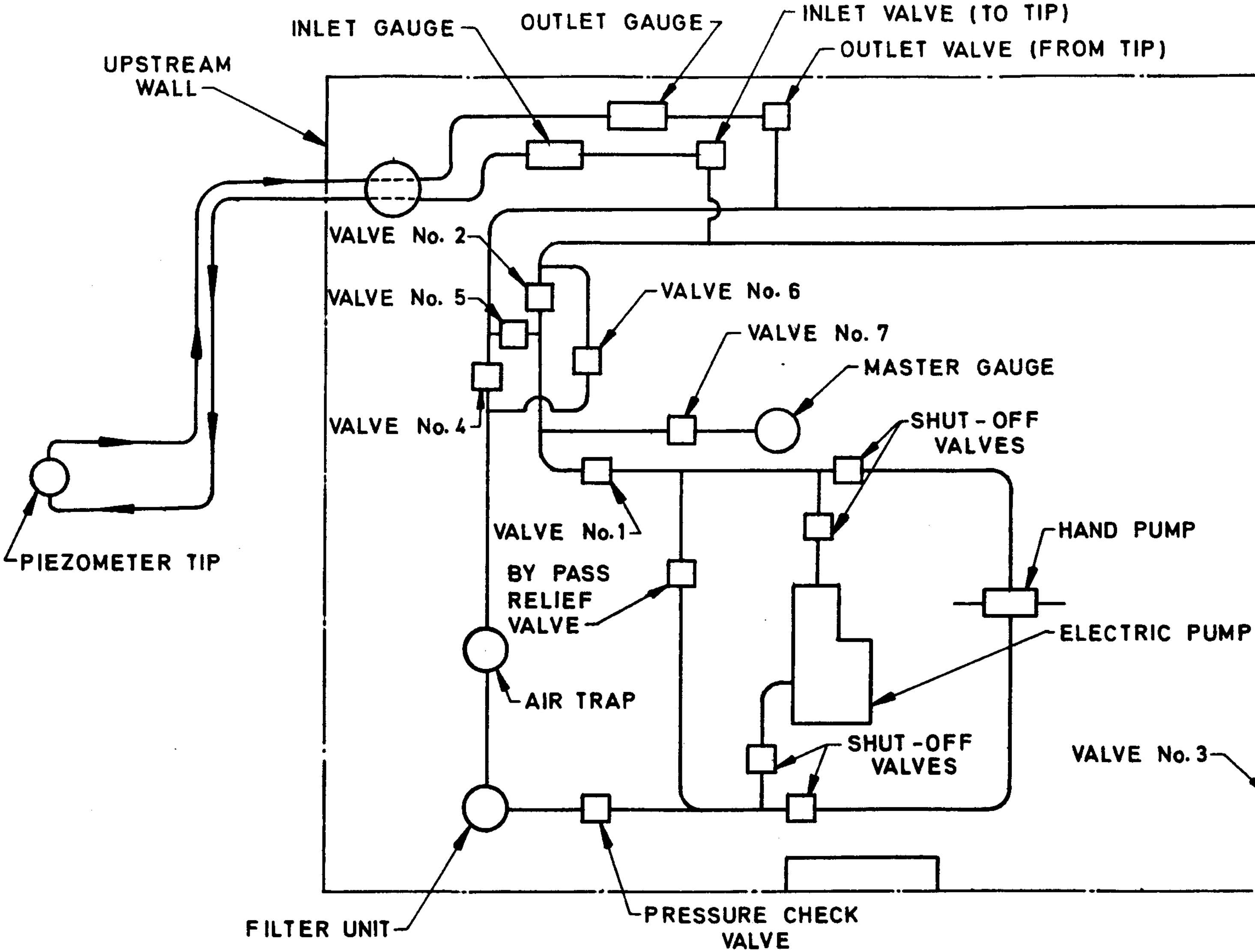


FIG. 6D SCHEMATIC PIPE DIAGRAM

7.2.7 *Water Filter Unit*

A cartridge-type water filter unit should be installed on the outlet line from the air trap. This filter unit will collect any sludge or particles of dirt or rust from the system as the lines are flushed. The slightly basic effluent from the filter cartridge will tend to retard bacterial growth within the system. During operation of the installation, the filter cartridge should be inspected at least each year and replaced if required.

7.2.8 *Valves*

The valves within the terminal well manifold system consist of hand-operated valves and automatic valves. All valves should be leakproof at the prescribed pressures and rust-proof and of the no-volume-change type. The hand-operated valves consist of a filter and bleeder valve for the air trap, inlet and outlet valves on the electric and hand-operated pumps, inlet and outlet valves on each of the piezometer and the following numbered valves as designated in Fig. 6D.

Manifold pressure valve	:	Valve No. 1
Inlet flushing valve	:	Valve No. 2
Manifold flushing valve	:	Valve No. 3
Outlet flushing valve	:	Valve No. 4
Manifold outlet valve	:	Valve No. 5
Manifold inlet valve	:	Valve No. 6
Safety valve on master gauge	:	Valve No. 7

With the exception of the manifold pressure valve, valve No. 1 which is a globe-needle valve, all the other hand-operated valves are of the plug shut-off type. Valve No. 1 is a slow operating valve to permit throttling the pressure from the pumps as it is applied to the manifold system and the external piezometer circuits.

The automatic valves in the manifold circulation system are the bypass relief valve and the pressure check valve. The bypass relief valve is preset to approximate the maximum positive pressure on the Bourdon-tube gauges. When this valve is first installed, sufficient pressure should be applied to open (crack) the valve to assure its proper operation.

The check valve is located between the pumps and the cartridge type water filter unit. It will prevent back pressures in the filter unit and especially into the plastic air trap when the bypass relief valve operates.

7.3 Electrical Transducers and Readout Equipment

In place of the conventional readout system using pressure gauges which form a fairly complex and elaborate arrangement taking up a large space in the terminal well, electrical transducers and readout system may be employed to take observations of pore pressure changes.

7.3.1 A typical arrangement of a transducer readout panel is illustrated in Fig. 9. The arrangement shows the tubes from the piezometer tips are connected to the manifolds of the transducer panel having ball valves fitted to each tube termination points. The electrical transducer is connected at the one end of manifold connecting the outlet tubes from the piezometers. A provision is given to connect the transducer at any time to a calibrating device like a dead weight pressure gauge tester for periodic calibration. A master pressure gauge is connected to the manifold which connects the inlet side of the piezometer tubes which in turn can be connected to the transducer independently at any time to have periodic cross check of the readings of each.

7.3.2 A digital indicator or suitable type should be connected to the transducer to read the pore pressures.

7.3.3 Data acquisition system with automatic recording of data may also be employed for collection of data at predetermined interval. A suitable automatic switching arrangement for opening and closing of inlet and outlet valves should be provided with the help of solenoid valves for automatic recording of data.

8 PROCEDURE FOR INSTALLATION

8.1 Placing Piezometers in Foundation

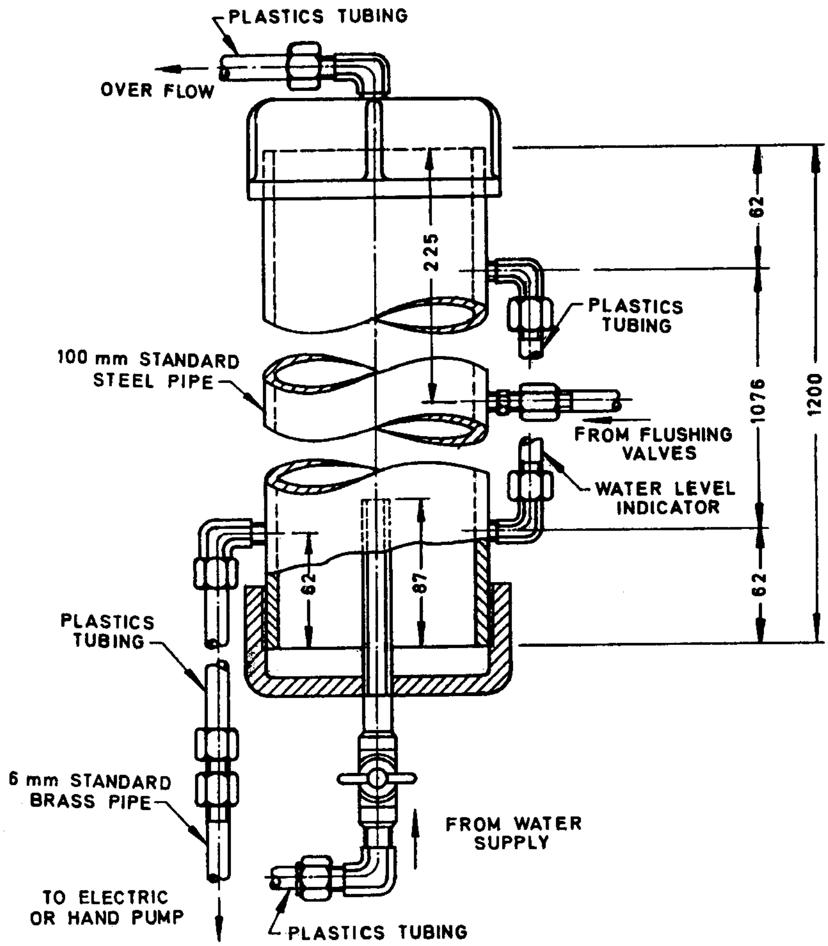
Foundation piezometers are installed in 100 mm minimum diameter holes bored into the dam foundation. Casing of these holes usually is required to maintain the holes during installation of the piezometer tip assembly. The holes may be bored by jetting, or by some type of drilling equipment such as percussion or diamond drilling depending on local conditions and the type of equipment available. No drilling mud should be added to the water during drilling operations. Casing should be removed after the foundation piezometer tip assembly is placed in position. If practicable, each hole also should be logged for its entire depth.

8.1.1 *Locating Foundation Piezometers*

Foundation piezometers should be installed along a single cross-section of the embankment unless special foundation conditions require their staggering. Individual holes should be drilled for each piezometer assembly. The elevation and location for each piezometer tip should be established to the nearest 30 mm.

8.1.2 *Backfilling the Holes*

Before the casing is removed from a bored hole, the lower 300 mm under the foundation piezometer tip should be backfilled with saturated sand. When installing the foundation piezometer tip, it is usually



All dimensions in millimetres.

FIG. 7 STEEL AIR TRAP

encased in a cloth sack containing filter sand. The sack may be encased in a plastic-mesh basket to ensure proper centering of the tip and to retain a cylindrical form during installation. The 8 mm OD tubing should be connected to tip, and the piezometer assembly shown in Fig. 2 should be lowered to the desired depth in the foundation. Removal of casing from the hole and backfilling around the piezometer assembly, first with saturated sand and then with the clay slurry, should be performed in short increment. The completed assembly for all foundation piezometers should be covered by a minimum of 450 mm of power tamped earth materials of the foundation excavation line, before heavy equipment is permitted to pass.

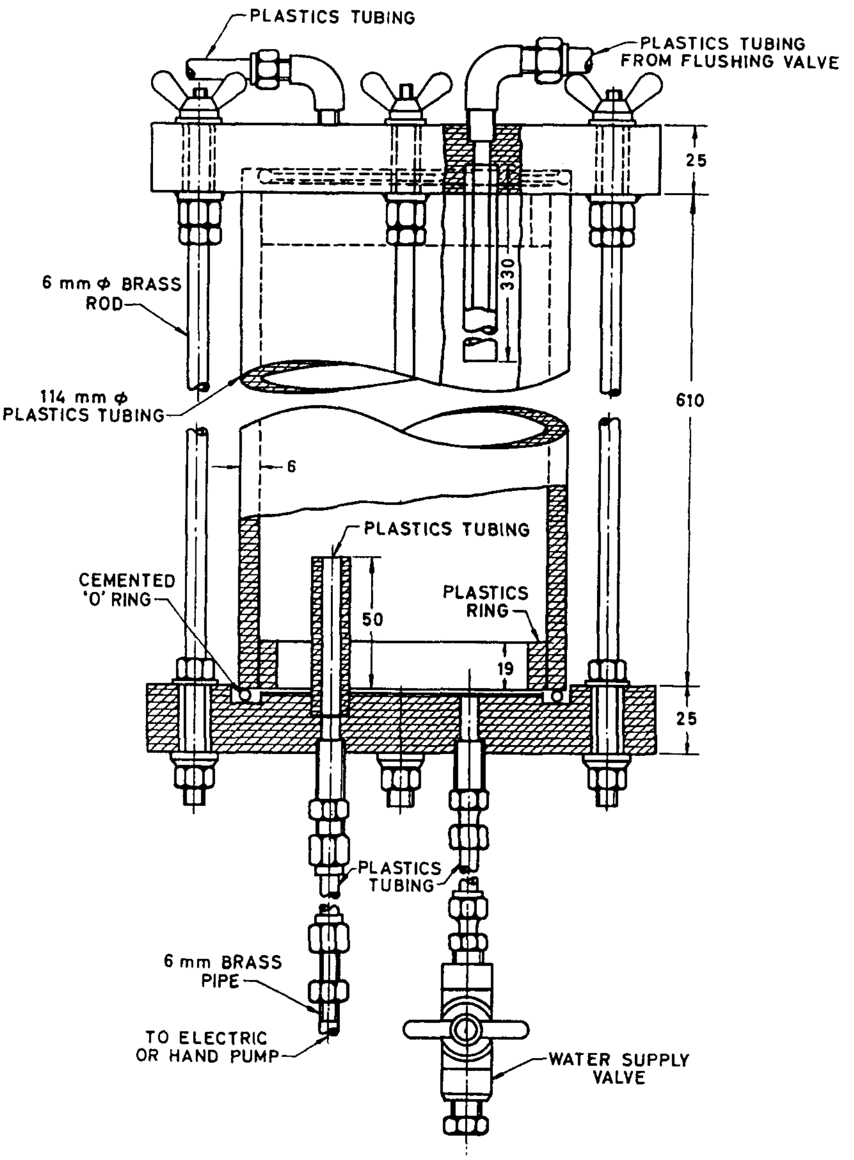
8.2 Placing Piezometers in Embankment

Embankment type piezometers are placed in shallow trenches laid at right angles to the main trenches which carry the connecting tubing from all the tips. The main trunk trenches are offset 600 to 900 mm from the location of piezometer tips. The tubing is surrounded with compacted selected fine material.

In order to avoid interference with embankment placing operations, trenches for the piezometer tubing should be excavated only as far ahead of trench backfilling operation as construction conditions permit. All trenches should be on a level grade, or on a grade either ascending or descending from the entrance pipe at the terminal well. Reversal of grades in a trench can produce air locks in the piezometer lines and should be avoided. Installation of the tubing in nearly horizontal runs and in vertical steps in satisfactory.

8.2.1 *Locating Embankment Piezometer Tips*

When an embankment type piezometer tip is installed at an elevation higher than the terminal well the tip should be placed slightly above the bottom elevation of the main trench. Conversely, an embankment type tip at a lower elevation than the terminal well should be placed slightly lower than the elevation of the main



All dimensions in millimetres.

FIG. 8 PLASTICS AIR TRAP

trench. In order to remove air from the tubes, each piezometer circuit should be filled with fluid before the tip is buried in the embankment. Rubber sheeted wood blocks and a 'C' clamp should be used to cover the tips during the filling of lines. The piezometer lines may be filled by circulating fluid from terminal well or by connection to a temporary pumping set or using a hand pump.

8.3 Trenches

8.3.1 *Main Trunk Trenches*

A 450 mm × 900 mm wide trench is satisfactory for carrying the piezometer tubes across the embankment. The depth of a trench is determined by the number of tiers of tubes to be placed. Each tier of tubing should be placed with a minimum of 12 mm of selected fine material, typical of the adjacent embankment, separating each tube. The depth of the trench required for tubing should provide for a minimum of 75 mm of selected material between successive tiers of tubes and also over the highest tier of tubes. A minimum of 450 mm of embankment material should then be placed to complete the backfill to existing embankment level.

8.3.2 *Offset Trenches*

The piezometer tips are placed in offset trenches excavated at right angles to the main trench at the required station and offset shown on the installation drawing. Excavation for the offset trenches usually is performed by hand in order to minimize the disturbance of the embankment adjacent to the tip.

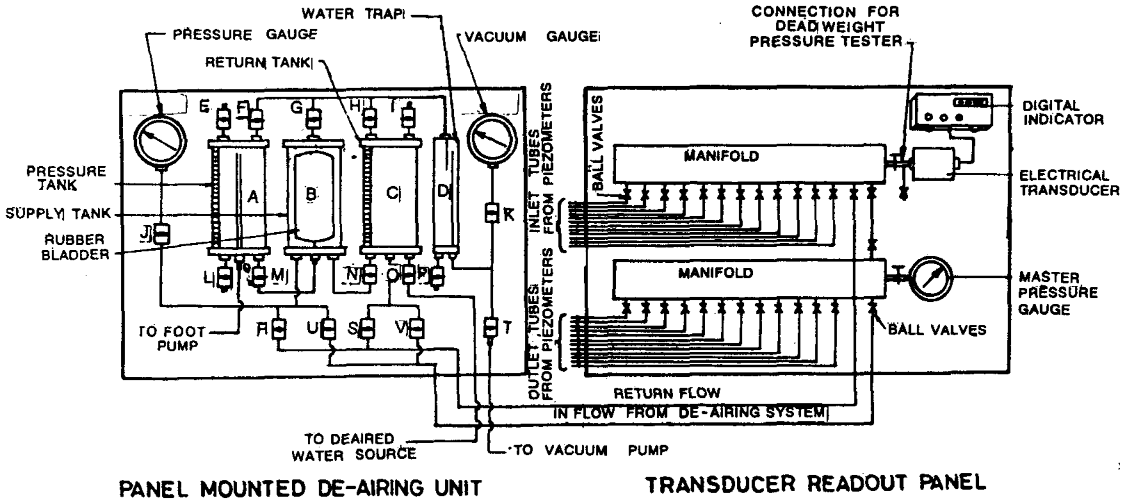


FIG. 9 ELECTRICAL READOUT SYSTEM

8.3.3 *Down Stream Trenches*

The piezometer tubes are brought upto downstream face of the dam through the main trunk trench. Thereafter the plastic tubing is laid in a trench of suitable cross-section parallel to the downstream fair upto the terminal well. The trench is backfilled with soil as given in **8.3.5**.

8.3.4 *Backfill Material and Its Compaction in Trenches*

Impervious or semi pervious backfill material immediately adjacent to the embankment type tips and adjacent to the piezometer tubing should be carefully selected or screened, if required, to eliminate material retained on the 4.75 mm IS Sieve. No pockets of porous material should be permitted in the backfill of the trenches. This backfill should have moisture content similar to and should be compacted to densities equivalent to that obtained in the adjacent embankment material. The backfill around the embankment piezometer tips should be selected fine material typical of the adjacent embankment and should be compacted in approximately 100 mm layers. Pneumatic or gasoline powered portable hand tempers are recommended to compact the backfill. Compaction of the 100 mm lifts of typical material above the layer of tubing may be accomplished by wheels or rubber tyred equipment, by power tamping, or by other suitable methods.

8.3.5 *Backfilling Procedure*

After the trench has been cleaned and levelled, spread a 50 mm thick protective cushion of selected fine material, typical of the adjacent embankment, in the bottom of the trench and place the first layer of tubes, individual tubes should be separated by approximately 12 mm. The tubes may be evenly spaced and identified by constructing a rack made of wood, similar to a hay or gardenrake. A hinged top board will permit access to the device and keep the tubes in order as the rake is dragged along the trench. Tubing should not be stretched taut prior to backfill. Before backfilling a slack of 1 to 1.5 percent should be uniformly distributed in each tube in order to compensate for differential settlement along the lengths of tubing.

8.3.6 *Bentonite Cut-Off*

During the backfill of the trenches, a plug approximately 300 mm wide, consisting of a mixture of 5 percent bentonite (by volume) and 95 percent embankment material should be placed in the trenches at 15 m intervals, or midway between the piezometer tubes, whichever distance is smaller. When the trench passes through the impervious zone of the dam, cut-off intervals should be so adjusted as to have on cut-off at the downstream face of impervious core. These plugs or cut-offs reduce the possibility of seepage through the embankment along the backfilled trenches. These cut-offs should extend at least 300 mm beyond the periphery of excavated main trench and be compacted to the top of the main trench.

8.3.7 *Rise Pipes*

When a group of piezometer tubing is to be extended vertically within the embankment, two methods are adopted for extension. When the rise is small, for example 1 to 2 m, the tubing may be bundled together and installed within a length of pipe made from corrugated iron sheet or from oil barrels with their ends removed and connecting straps welded to the

outside of the barrels. However, when the vertical rise is more, it is better to fabricate a collar 400 mm to 500 mm in diameter around the upper end of a 2 m to 3 m length of relatively thin walled steel pipe and then jack the pipe to progressively higher elevations as required. In either case the tubing within the riser should be bundled and taped together, inserted inside the pipe and the tubing installed with approximately 300 mm radius both below and above the riser section. In addition, selected fine materials typical of adjacent embankment should be placed around the bundle of tubes to completely fill the riser section. Mounting of the embankment material should be performed around the riser and such mounting should be compacted by pneumatic tampers in 100 mm lifts.

8.4 Embankment Placement Over Trenches

Specified embankment placement methods are used over the completed piezometer trenches.

9 FLUID FOR PEIZOMETER SYSTEM

9.1 Air-free clear water containing a minimum of soluble salts is recommended for filling the piezometer system. For convenience in handling, fluid for the piezometer installation should be prepared in quantities of approximately 25 or 50 litres. To each of the container holding 50 litres of clear water add 2 teaspoonfuls of a 25 percent solution of quaternary ammonium compound (QAC). This resultant solution is recommended for initial introduction into the twin tube piezometer system as a bacterial inhibitor and as a wetting agent. However, during the recommended annual flushing of operating piezometer systems, it is recommended that 4 teaspoonfuls of the 25 percent QAC solution or the alternative solution be added to the water reservoir or tank within the terminal well. A practicable, the solution should be warm when it is introduced into the piezometer lines. However, the temperature of the solution should not exceed 50°C, since too hot a water can soften the plastics.

9.1.1 *Introducing Fluid into Piezometer System*

The following procedures are recommended for introducing fluid into the piezometer system:

a) Prepare approximately 150 litres of piezometer fluid consisting of 2 teaspoonfuls of 25 percent QAC or the alternative solution added to each 50 litres of air-free clear water. Fill water container (reservoir water) in terminal well.
b) Check the entire manifold system in the terminal well to be certain that all valves are closed. Then open the filter valve and the bleeder valve to the air trap. Fill the air trap with fluid to within 80 mm from the top of the plastic air trap (*see* Fig. 8) or to the top of the water level tubing on the steel air trap (*see* Fig. 7). Then close these valves.
c) Open the inlet and outlet valve to the electrical/hand pump, and in sequence, valves No. 7, 2, 3, 4 and 1 (*see* Fig. 6). Start pumping and continue circulation until no further air bubbles appear at the air trap. In the same sequence close all valves except the valves on the pump.
d) Open in sequence valves No. 7, 5, 3, 5, 1 and flush. Continue pumping to purge the air from the circuit, and in the same sequence close all the valves except the valves on the pump.
e) Open in sequence valves No. 7, 2, 6, 1 and flush. Continue pumping to purge the air from the circuit and in the same sequence close all the valves.
f) Add fluid to the air trap when the water level shows less than half full.

9.1.2 *Introducing Fluid into External Piezometer Circuits*

To extend the filling and flushing to the external piezometer tips, follow the procedures given in **9.1.1** (a) and **9.1.1** (b) and proceed as follows:

a) Open pump valves and valves No. 1, 2 and 4. Also slowly open the inlet and outlet valves for one piezometer and flush. Then close valves No. 2 and 4. This is direct flushing.
b) Open valves No. 5 and 6 continue flushing. Close all valves. This is reverse flushing.

9.1.3 *Flushing Procedure*

9.1.3.1 The flushing of external circuits as given in **9.1.2** (a) and **9.1.2** (b) should be continued until no further air bubbles appear at the air trap. However, pump should be continued for not more than 16 min on any one piezometer circuit during a single flushing operation. After flushing is completed, close all valves in the terminal well including the pump valves.

9.1.3.2 From the explanation given in **7.2.8**, valve No. 1 should be used to throttle or control the pressure being applied during the flushing operation. Pumping pressures should be limited to approximately 10 mH_2O (gauge) in excess of a negative tip constant for a piezometer tip.

9.1.3.3 After individual piezometer or the entire piezometer system has been placed in operation, pumping pressures should be limited to 10 mH_2O in excess of the average of the pressures observed on the separate (100 mm diameter) gauges for an individual piezometer.

9.1.3.4 During construction of the dam, flushing should be performed to place manifold system in operation as soon as practicable. After individual piezometer circuits are placed in operation, the circuits should be flushed at approximately monthly intervals, until the circuits to the respective piezometers are free of air. After the earth dam has been placed in operation, individual piezometers should be flushed once each year, both to eliminate any air from the circuit and to dislodge and inhibit bacterial growth. Flushing of piezometer circuits should be performed at least one day before regular readings are obtained.

Both direct and reverse flushing should be performed on external piezometer circuits as outlined in **9.1.2** (a) and **9.1.2** (b), to complete the flushing of each tip. After flushing has been completed check the residual pressure on the pair of (100 mm dial) gauges for each piezometer. If pressure differ by more than 60 cm H_2O on 15 m H_2O on capacity gauges or by 3.0 m H_2O on 150 m H_2O capacity gauges, repeat the flushing of the line showing the lower pressure to bring the gauge pressure within the desired limits.

10 PROCEDURE FOR OBSERVING PORE PRESSURES

10.1 Response Time

After the completion of the flushing as per **9.1.3.1** for a piezometer tip note down the inlet and outlet pressure gauge readings and time. Continue the set till the gauges show constant readings. The time required to achieve the constant gauge reading is the response time of that piezometer tip. The pore pressure observations of each piezometer tip should not be taken prior to the completion of the response time for that piezometer tip.

10.2 Pressure Readings with Separate Gauge

a) Read the pressures on the individual (separate) 100 mm dial gauges for each piezometer.

b) If the inlet and outlet gauges pressures agree within the desired limits (60 cm H_2O for 15 m H_2O gauge, 1.5 m H_2O for 60 m H_2O gauge; 3.0 m H_2O for 150 m H_2O gauge) obtain the arithmetical average.

c) The tip constant for the separate gauges is the difference in elevation between the pair of gauges for tip and the corresponding piezometer tip. A plus constant results when the tip is below the elevation of the gauges and a minus constant results when the tip is above the level of the gauges.

d) Add the average gauge pressure to the tip constant and record in the appropriate column on Form I, given in Annex A.

10.2.1 *Pressure Readings with Master Gauges*

a) Observe the average gauge pressure on the pair of separate gauges for a particular piezometer tip.

b) Follow the procedures for flushing the manifold system as described in **9.1.1**.

c) Continue pumping. Open in sequence valves No. 1, 2, 6 and 7. By throttling valve No. 1 and slowly closing valve No. 6, it will be possible to set the desired balancing pressure (from the small gauges) on the master gauge. After setting the desired balancing pressure, close all valves and stop pumping. Record this inlet setting pressure on Form II, given in Annex A and crack the desired inlet valve (to the tip) for a piezometer. Read and record the responding pressure observed on the master gauge. Then close the inlet valve (to the tip).

d) To obtain the outlet master gauge reading, first resume pumping and then open in sequence valves No. 1, 4, 5 and 7. Throttle valve No. 1 as before and slowly close valve No. 4 to obtain the outlet setting pressure on the master gauge. Then close all valves and stop pumping. Record the outlet setting pressure and then crack the desired outlet valve (from the tip) for a piezometer. Read and record the responding pressure on the master gauge, using the appropriate column on Form II. Then close the outlet valve.

e) Add the average inlet and outlet master gauge pressures to the tip constant for the master gauge and the specific piezometer tip (difference in elevation between the master gauge and the tip) and obtain the average pressure at the tip. Record as appropriate on Form II.

f) When a vacuum pressure is indicated on the small gauges for a tip, close the inlet valve on the hand pump, open valves No. 1 and 7, and valve No. 2 or No. 5, depending on the desired access line to the tip, and apply a suction stroke on the hand pump. Record this setting as observed on the master gauge on Form II.

g) Crack the desired inlet or outlet valve (to or from the tip) for the desired piezometer on which vacuum readings are required. Record the responding reading observed on the master gauge and close all valves.

h) Repeat as in (f) and (g) for the opposite valve (inlet or outlet) and record the responding vacuum reading on the master gauge. Close all valves.

j) After the dam is completed, readings from the average of the inlet and outlet separate gauges should be compared with those obtained by use of the master gauge at least once each year. These comparative readings should be obtained, preferably on the same day.

10.2.2 *Adjustment and Calibration of Gauges*

No repairs should be made in the field to the movements or to the bourdon-tube elements of any of the gauges. As the gauges are mounted in the terminal well, the brass pipe caps should be removed from the 100 mm dial gauge to release the capping pressure. After mounting, each gauge should be tapped lightly to assure a no pressure condition. Then the gauges should be zeroed using a needle puller and a small hammer. This checking should include a comparison reading by use of the master gauge. The individual separate gauge is then disconnected and pipe plug inserted immediately in the tube that holds the gauge stem. Finally, flush the system free of air and leave a pressure in both tubes equal to the pressure recorded on the master gauge before the small gauge was removed till a new separate gauge is installed. The pressure gauges should be calibrated at regular intervals.

10.3 Readings with Electrical Transducers

10.3.1 De-airing of the piezometer lines should be done as described in **9.1.3**. Figure 9 shows an alternative arrangement for de-airing the piezometer. In the arrangement three acrylic plastic tanks are used, two of them fitted with scales to measure the volume of water flowing into or out of tanks. Air is pumped into the top of tank *A* causing a flow into the rubber bladder in the second tank and this forces air-free water into the piezometer system. The flow is measured by the fall of water into tank *A* and this checked by the scale on tank *C*, where the return water is collected. The water in cylinder *B*, which circulates through the piezometer lines, must be de-aired and this is achieved by boiling under vacuum. Boiling is continued for a period of about 15 min. The air free water is then drawn off and into cylinder *B* of the de-airing apparatus. With a large number of piezometer tips served by one de-airing unit, a constant pressure pump may be used to circulate the water. The cylinders having a capacity of 5 litres is sufficient to de-air 800 m of tubing. When de-airing the hydraulic piezometer, care should be taken that the pressure at tip should not exceed the overburden pressure, otherwise hydraulic fracture may occur.

10.3.2 Depending on the elevation of the piezometer tips it could be possible to ascertain the piezometer which will read the maximum value of the group of piezometers connected to the panel. As far as possible this estimate should be taken to guide the operation of opening of values pertaining to each piezometers for taking the readings.

Open the inlet valve of the piezometer pertaining to the piezometer estimated to give the higher reading. Keep all valves shut. Open the valve to the transducer. Wait for the reading to be stabilized. After noting down the reading of this piezometer close the inlet valve of the piezometer and open the valve pertaining to the next piezometer. The piezometer readings should be taken as far as possible in descending order of the pressures. This procedure will help stabilizing the pressures quickly when switching from one piezometer to another. The reading of each piezometer should be recorded as required.

10.3.3 If automatic data acquisition unit is used with the transducer panel, the interval and mode of selection of piezometers should be programmed in the data acquisition set up.

11 RECORDED TESTS

Record tests of soils near the embankment piezometer tips should be made while they are being installed. Grain size distribution, specific gravity and consistency limit test should be conducted besides average field density and moisture content of soil layer in which the tip is installed. When measurement of construction pore pressures is contemplated, laboratory construction pore pressure tests should be carried out. Permeability should also be found out for compacted soils near piezometers.

12 PRESENTATION

12.1 A cross-section of the dam showing locations of tips may be maintained in the terminal well.

12.2 Correlation of the pore pressures and settlement of observations should be done if both the data are available for the same location. This study would need the consolidation characteristics of the fill and the parameters controlling dissipation. Besides the following graphs should be prepared:

a) *Pore pressure elevation* versus *time* — The embankment surface elevation is also plotted on the same graph. From these studies an idea can be formed as to how far the pore pressures get influenced by an increase in the height of embankment as the construction progresses and whether any dissipation with reference to time is noticeable.

b) *Contours of equal pore pressure* — During construction and end of construction,

contours of equal pore pressures should be drawn in the cross-section. This will determine whether construction pore pressures at the outside edges of the core are reducing due to drainage in the adjacent more pervious zones.

13 FREQUENCY OF OBSERVATION

The frequency of readings on the piezometer installation to be recorded in duplicate during construction and during operation of the earth dam should be as given in Annex B. A proforma for the record of observations is given in Annex A.

14 MONTHLY REPORT

Each progress report should include the pressure readings taken during preceding month and a record of elevations and locations to the nearest 30 mm for all piezometers intalled. A field drawing should accompany the report to show cross-sections of the embankment to the nearest 0.5 m at the time the latest pressures were observed.

ANNEX A

[*Clauses* 10.2(d),10.2.1(c) *and* 13]

PROFORMA FOR RECORDING OBSERVATIONS

Form I Piezoemeter Readings Separate Gauge

Dam :

Project :

Ref drawing :

Reservoir water elevation :

Date of observation:

Observer:

Sheet No.:

Tail water elevation:

El of Separate Gauge Station

R_1 of Dam

Piezometer No.	R_1 of Piezometer Tip	Separate Gauge Readings				Average Gauge Reading	Tip Constant	Average Pressure at Tip
		Inlet		Outlet				
		Setting	Reading	Setting	Reading			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

Form II Piezometer Readings Master Gauge

Dam :

Project :

Ref drawing :

Reservoir water elevation :

Date of observation:

Observer:

Sheet No.:

Tail water elevation:

El of Master Gauge Station

R_1 of Dam

Piezometer No.	R_1 of Piezometer Tip	Master Gauge Readings				Average Gauge Reading	Tip Constant	Average Pressure at Tip
		Inlet		Outlet				
		Setting	Reading	Setting	Reading			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)

ANNEX B

(*Clause* 13)

FREQUENCY OF READINGS

Sl No.	*Readings*	*Progress Report During Construction — No Reservoir, Frequency of Readings*		*Periodic Report — Post Construction Frequency of Reading*	
		Construction	Shut Down	First Year and Second Year	Regular
(1)	(2)	(3)	(4)	(5)	(6)
i)	Separate gauge piezometer readings	15-day intervals	Monthly intervals	Once for every predetermined change in reservoir level which should be fixed according to the size and importance of the structure and the characteristics of the reservoir. In any case the frequency should not be less than once in a month during first year and second year and not less than once in three months thereafter	
ii)	Master gauge piezometer readings	Monthly intervals	Two-month intervals	Half yearly intervals	Yearly intervals (same month each year)

ANNEX C

(Foreword)

COMMITTEE COMPOSITION

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This Indian Standard has been developed from Doc : No. WRD 16 (322).

Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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Printed at Prabhat Offset Press, New Delhi-2